Characterization and Modeling of the Philippine Archipelago Dynamics using the ROMS 4DVAR Data Assimilation System

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LONG-TERM GOAL

The long-term goal of this project is to improve our capability to predict the inherent spatial and temporal variability near the Philippine Straits, and thus contribute to the development of reliable prediction systems.

OBJECTIVES

The primary focus is to provide a comprehensive understanding of the remote and local factors that control the meso- and submesoscale features in and around the Philippine Archipelago Straits. The main objectives are:

- to explore the effects on the Philippine Straits of remote forcing from the equatorial waveguides, throughflows, and adjacent seas mesoscale dynamics;
- to estimate the effects of local winds in generating meso- and submesoscale variability;
- to quantify the role of barotropic tidal forcing in promoting side wall eddies and internal tides;
- to study the role of abrupt changes in bathymetry in generating submesoscale variability; and
- to investigate the impact of variational data assimilation on the simulation and predictability of the meso- and submesoscale circulation features.

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APPROACH

The approach for accomplishing the proposed objectives is model simulation using ROMS (Shchepetkin and McWilliams, 2005) and its comprehensive ocean prediction and analysis system (Moore et al., 2004). Tidal forcing will be imposed using available global OTPS model.

ROMS is a three-dimensional, free-surface, terrain-following ocean model that solves the Reynolds-averaged Navier-Stokes equations using the hydrostatic vertical momentum balance and Boussinesq approximation (Haidvogel *et al.* 2000; Shchepetkin and McWilliams, 2005). The governing dynamical equations are discretized on a vertical coordinate that depend on the local water depth. The horizontal coordinates are orthogonal and curvilinear allowing Cartesian, spherical, and polar spatial discretization on an Arakawa C-grid. Its dynamical kernel includes accurate and efficient algorithms for time-stepping, advection, pressure gradient (Shchepetkin and McWilliams 2003, 2005), several subgridscale parameterizations (Durski et al., 2004; Warner et al., 2005) to represent small-scale turbulent processes at the dissipation level, and various bottom boundary layer formulations to determine the stress exerted on the flow by the bottom. Several adjoint-based algorithms exists for 4-Dimensional Variational (4DVar) data assimilation (Di Lorenzo et al., 2007; Powell et al. 2007), ensemble prediction, adaptive sampling, circulation stability (Moore et al., 2004), and sensitivity analysis (Moore et al., 2006).

WORK COMPLETED

A hierarchy of several regional, nested grids have been built at various horizontal resolutions: coarse (15 km), medium (5 km), and fine (1 km). The initial and lateral boundary conditions are from the 1/12° Global HYCOM with NCODA (provided by Joe Metzger and Harley Hurlburt), atmospheric forcing is from NOGAPS 3-hours, half-degree resolution, and the tidal forcing is from the global OTPS model. Several real-time forecasts in the Philippine Archipelago were carried out from May 17 to June 23, 2007. The daily forecasts, without data assimilation, provided support for the Philippine Experiment (PhilEx) Exploratory cruise and can be found at http://www.myroms.org/philex (Figure 1).

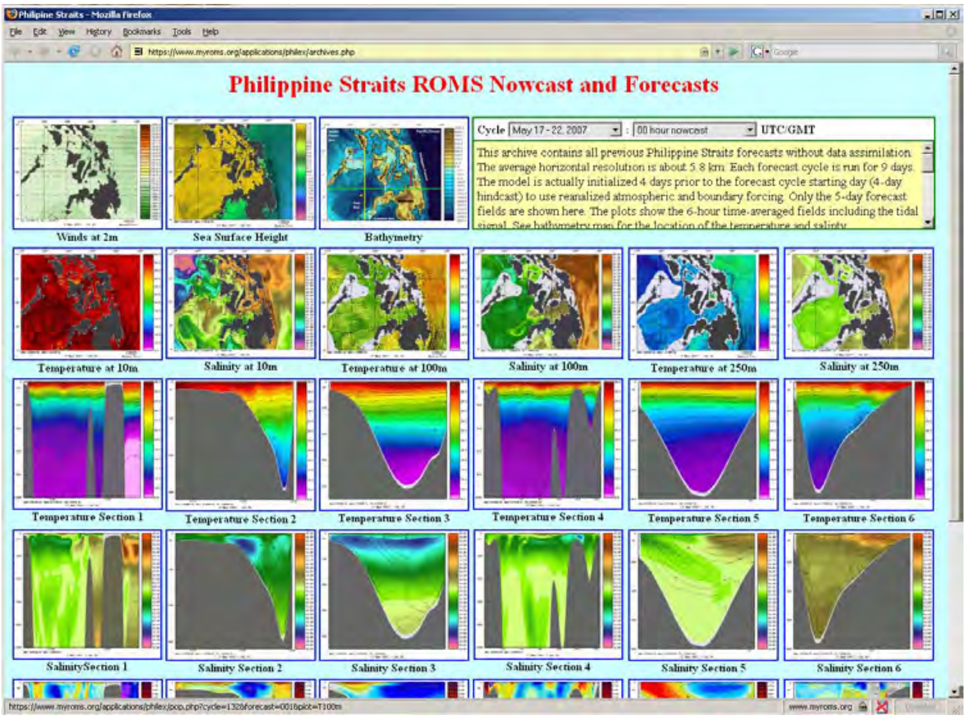

Figure 1. A screenshot of our Philippine Straits website http://www.myroms.org/philex showing the real-time ROMS forecast fields per cycle at various horizontal depths and cross-sections.

Each prediction cycle, updated daily, was run for 9 days (4-day hindcast and 5-day forecast). The model was initialized 4 days prior to the forecast cycle starting day to use reanalyzed atmospheric and boundary forcing.

RESULTS

A snapshot of salinity at 5m depth from the real-time forecast for June 5, 2007 is shown in Figure 2. It illustrates a strong inflow of fresher water from the South China Sea through the Mindoro Straight and intrusion of saltier water from the Pacific Ocean through the Surigao Straight (between Leyte and Mindanao) and San Bernardino Straight (between Luzon and Samar). Several strong buoyant eddies are created in the Sulu Sea, where the fresh and salty water meet. Interesting dynamics occur in the Bohol Sea, where the saltier Pacific water follows the northern pathway while fresher water from the Sulu Sea follows the southern pathway. The model correctly captures the location of a buoyant eddy in the Bohol Sea. A Comparison with data obtained during the Exploratory Cruise is shown in the lower panels of Figure 3.

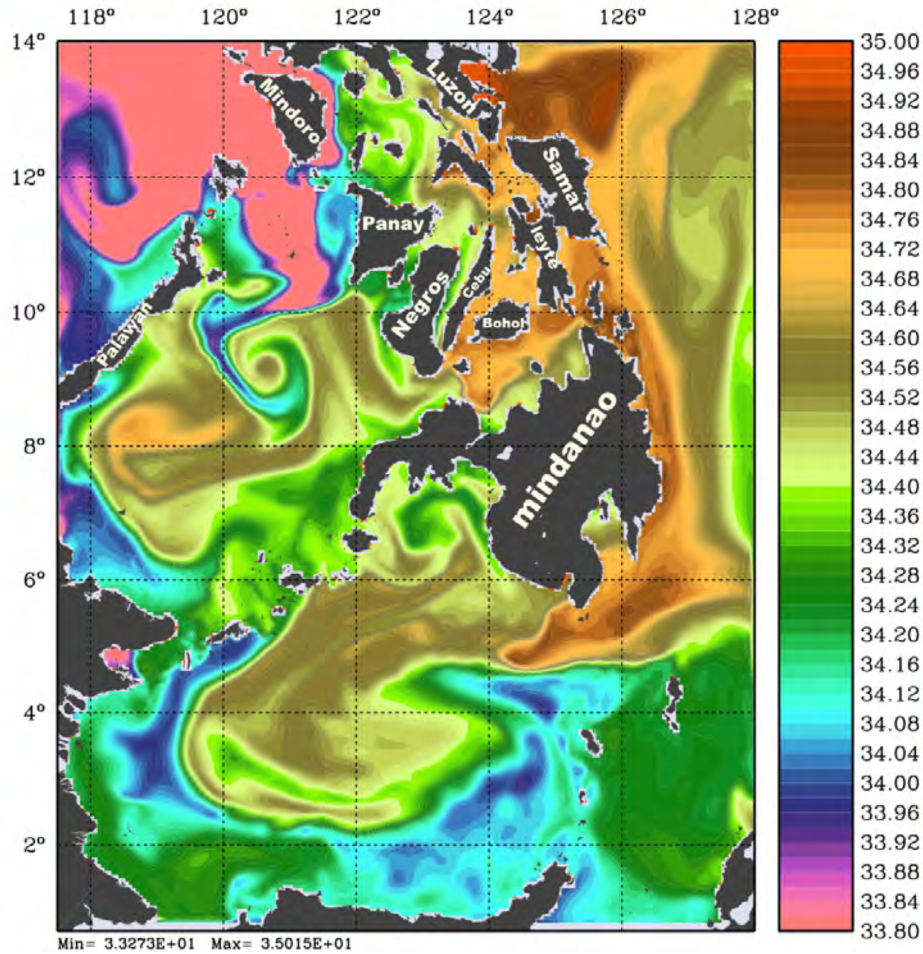

Figure 2. Real-time salinity forecast at 5m, June 5, 2007

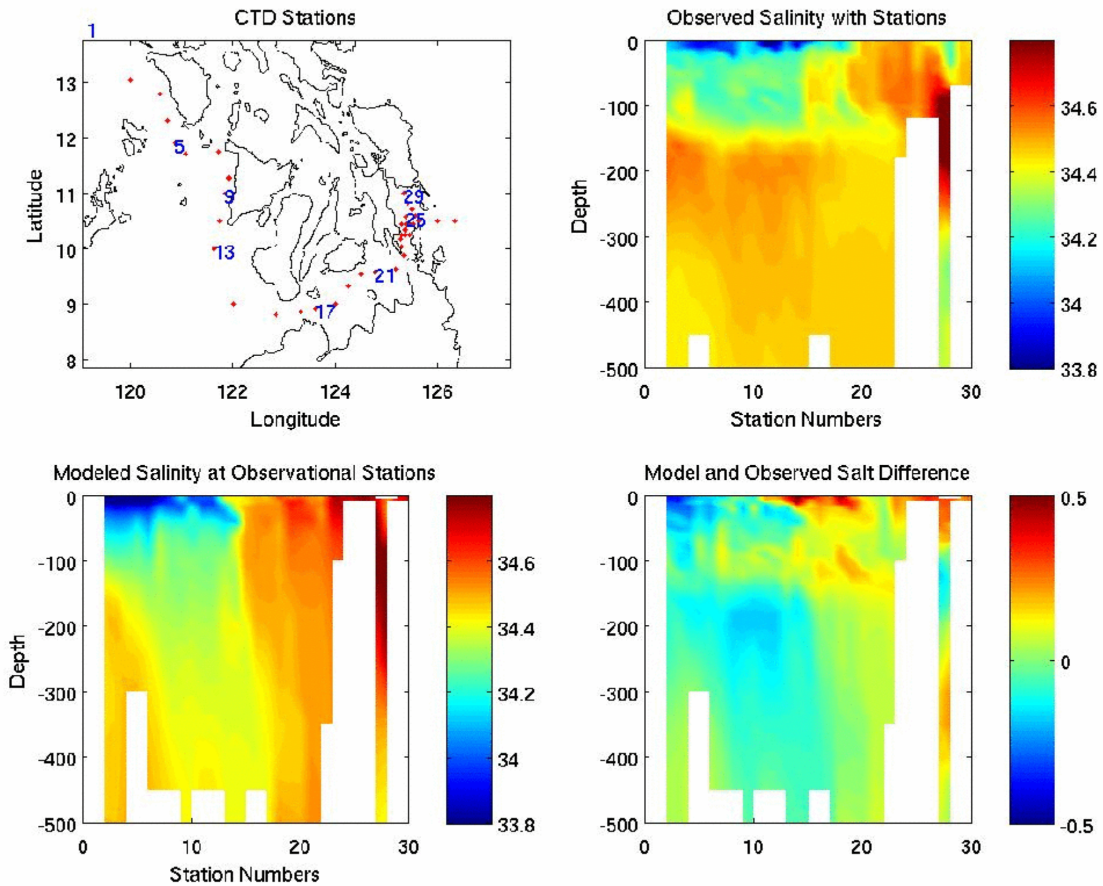

Figure 3. Salinity comparison between model and observations: CTD observations (upper left panel), observed salinity at CTD stations (upper right panel), model salinity interpolated at the CTD stations (lower left panel), and salinity difference between model and observations (lower right panel).

The model correctly captures the extent of the intrusion of fresh water (stations 1-10). The saltier Pacific Water transport is slightly exaggerated in the model and penetrates deeper down than the observations indicate. Comparison with temperature profiles from CTD, not shown, reveal that the model has a more diffuse thermocline than the observations. On average, the model is slightly warmer than the observations. We expect these discrepancies to be corrected with data assimilation.

As a preamble to the data assimilation experiments, the optimal perturbations and adjoint sensitivity analysis are currently underway to identify the validity of the tangent linear approximation, assimilation time windows, and observational operators. Three different metrics have been analyzed for the Mindoro, Bohol, Surigao, and San Bernardino Straits: (i) transport, (ii) velocity anomaly, and (iii) temperature anomaly. Early results indicate that bathymetry, temperature and velocity are crucial to obtain a good estimate of transport. Figure 4 shows the sensitivity (derivative) of transport through the 4 major straights toward the bathymetry (left panel), velocity magnitude (middle panel), and temperature (right panel) during May 4-9, 2007. The sensitivity to velocity and temperature is scaled by their standard deviation. The bathymetry sensitivity is scaled by the difference between model (smoothed) and real bathymetry. With this scaling, bathymetry can change the average transport by as much as 0.03 Sv (up to 30% percent of the transport in some places). The sensitivity to velocity and temperature is a couple orders of magnitude less. Although the model bathymetry is smoothed, the spatial structure of the velocity and temperature fields is still able to identify regions where a good estimate of transport is needed. We either need to improve the bathymetry representation in the model or have observations to assimilate into the model to correct possible circulation errors in those areas.

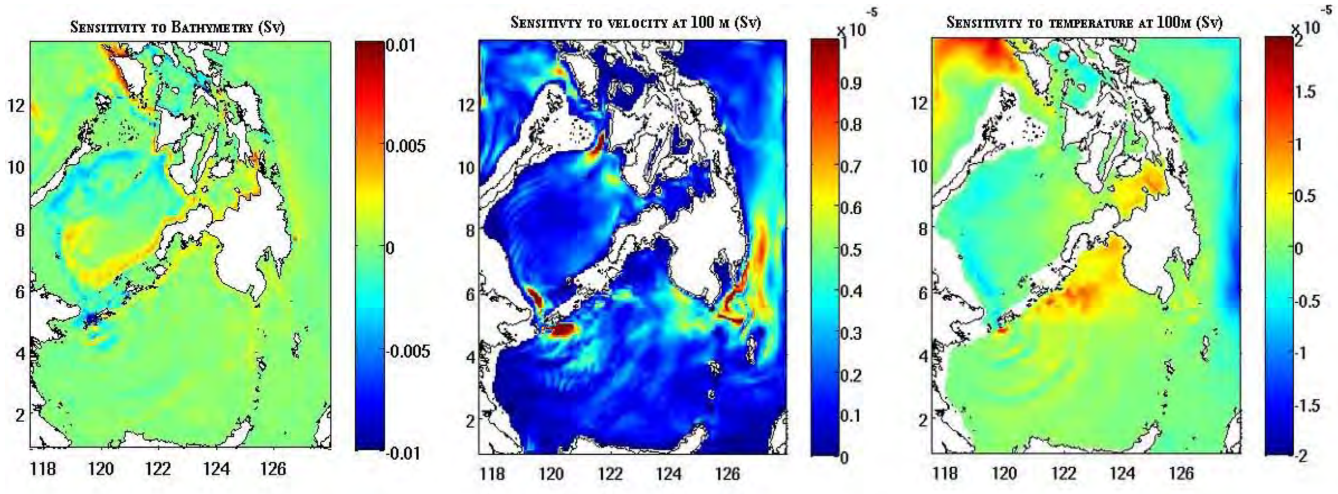

Figure 4. Sensitivity of transport (in Sverdrups) through the four major straights (Mindoro, Bohol, Surigao, and San Bernardino) to bathymetry (left panel), velocity magnitude at 100 m depth (middle panel) and temperature at 100 m depth (right panel).

IMPACT/APPLICATIONS

This project will advance our scientific understanding of the generation dynamics and predictability of meso- and sub-mesoscale eddies near straits.

TRANSITIONS

None.

RELATED PROJECTS

The work reported here is related to other already funded ONR projects using ROMS. In particular, the PI (Arango) closely collaborates with A. Moore and B. Powell (Intra-Americas Sea trials, http://www.myroms.org/ias) at University of California, Santa Cruz, A. Miller and B. Cornuelle (ROMS adjoint and variational data assimilation) at Scripps Institute of Oceanography, E. Di Lorenzo (Southern California predictability) at Georgia Institute of Oceanography, and J. Wilkin (Mid-Atlantic Bight variational data assimilation) at Rutgers University.

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PUBLICATIONS

None.